Geodiversity in Poland

Association for Geoconservation, Hong Kong

Geodiversity Workshop 3 celebrating The International Geodiversity Day

GEODIVERSITY OF EUROPE

30 MAR 2022

Geodiversity
- Very low
- Low
- Medium
- High
- Very High

Zbigniew Zwoliński

Institute of Geoecology and Geoinformation
Adam Mickiewicz University in Poznań, Poland
Chair of the International Association of Geomorphologists' Working Group on Landform Assessement for Geodiversity

Concepts of geodiversity

- Geological concept
- Geomorphological concept
- Ecological concept
- Integrated (complex) concept

Geodiversity connotations

Geomorphological concept

- Geodiversity of landforms is a landscape complexity from a geomorphological point of view and subject to assessment in the context of all morphogenetic systems of various types of landforms (Kostrzewski, 1998, 2011, Zwoliński, 2004, 2010).

Geodiversity connotations

Integrated (complex) concept

- Geodiversity includes the diversity of the Earth's surface in terms of geological structure, landforms, soil, climate, surface and underground waters, taking into account human impact.
- In this sense geodiversity is characterised much broader. This complex approach especially have evolved in Poland (Kozłowski 1997, 2004; Kostrzewski 1998, 2011; Degórski 2001; Zwoliński 2004, 2009, 2014; Kot 2006; Zwoliński, Stachowiak 2012, Najwer, Zwoliński 2014, Najwer et al. 2016, 2022, Jankowski et al. 2020) and increasingly appearing in the world literature (*Stanley 2001; AHC 2002; Serrano Ruiz-Flaño 2007, 2009; Benito-Calvo et al. 2009; Hjort, Luoto 2010, 2012; Pellitero et al. 2011, 2014, Gray 2013*).

Geodiversity and geoheritage

Zwoliński 2015

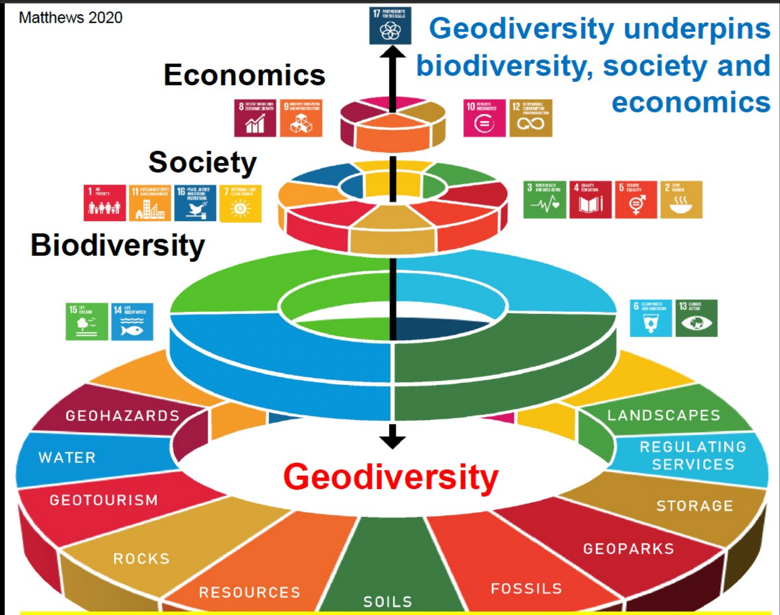
Geodiverse landscape

From the geodiversity perspective, a geodiverse (or outstanding) landscape is a feature which is (Zwoliński 2004):

- rare,
- unique,
- an exceptionally well-expressed example of its kind,
- have a special importance within a given region.

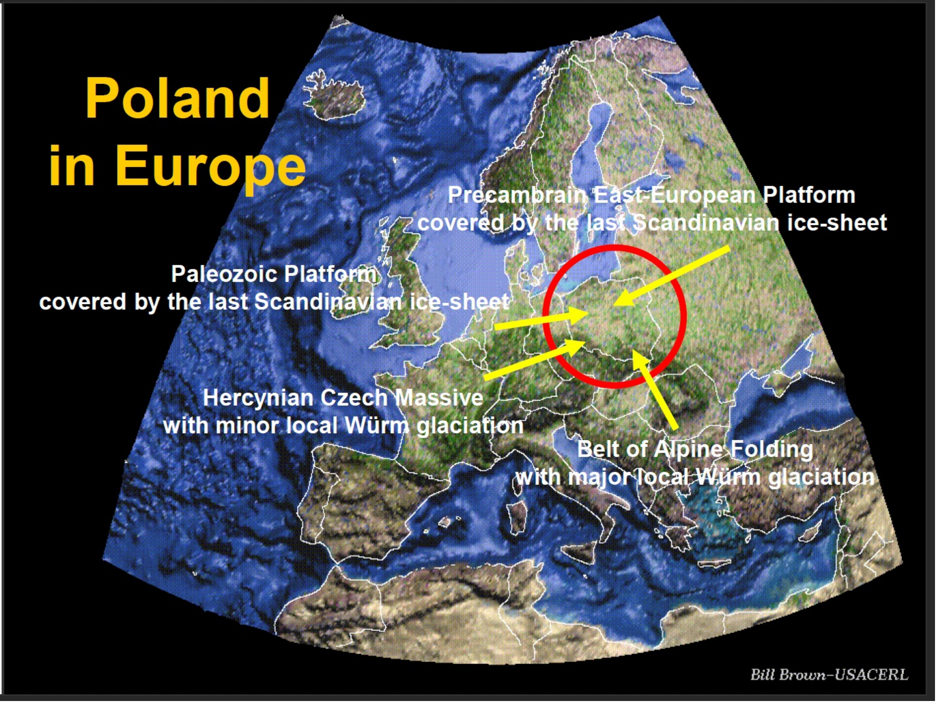
Geodiversity context and Sustainable Development Goals

Matthews 2020

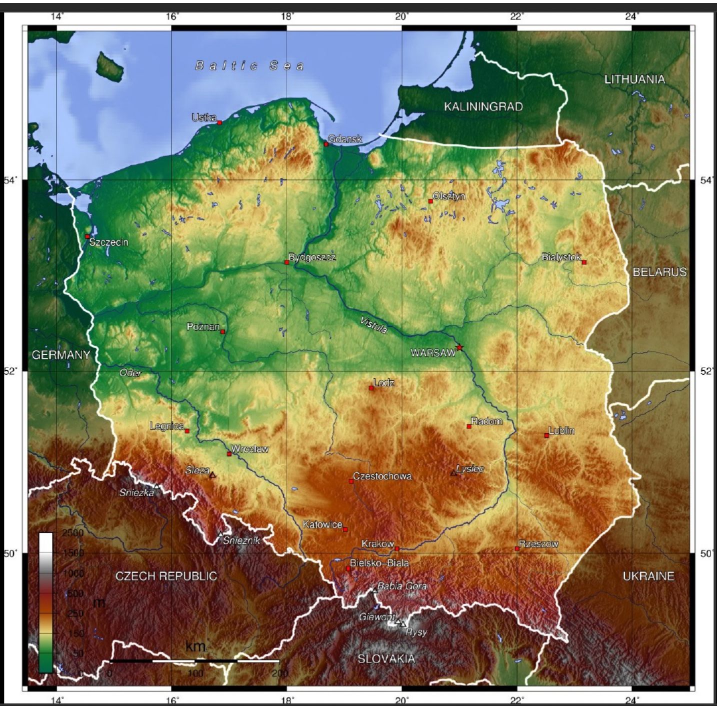


Sustainable Development Goals and Geodiversity
12 goals and 55 targets

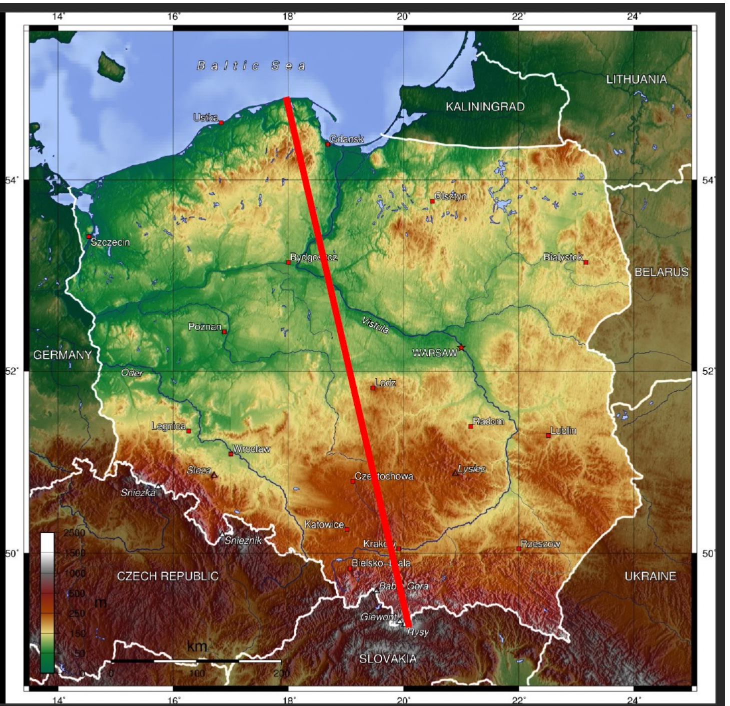
Poland in Europe



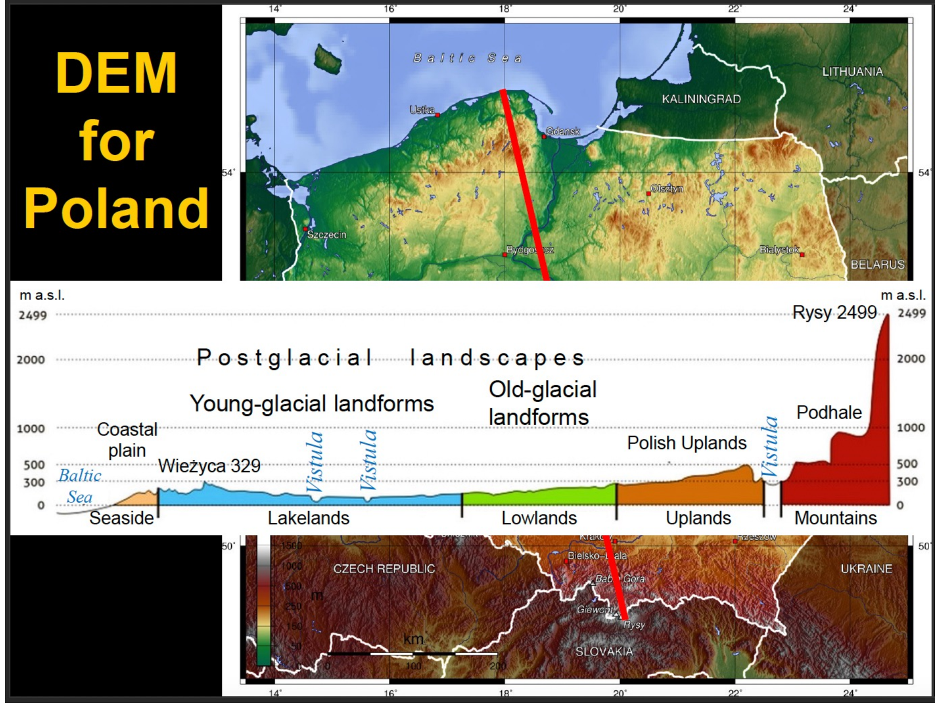
DEM for Poland



DEM for Poland

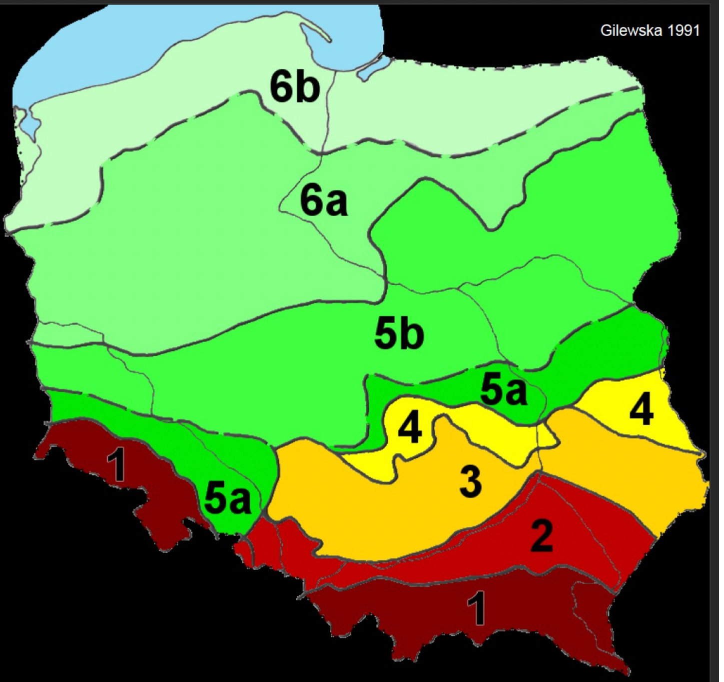


DEM for Poland

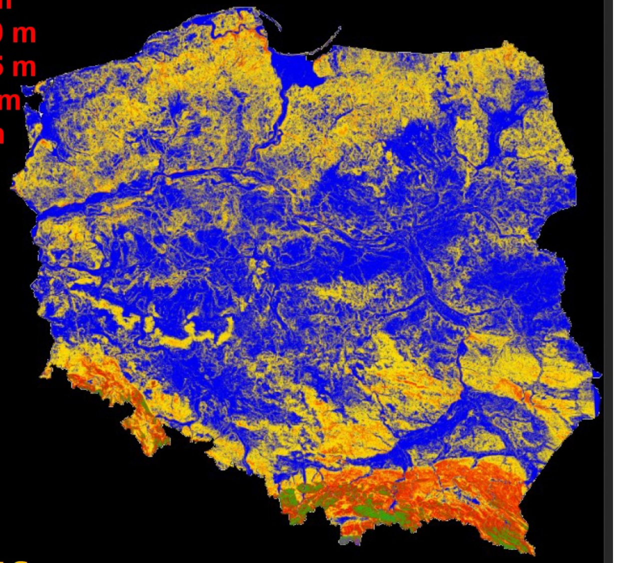


Morphogenetic zones:

6b - a young-glacial area covered by the Pomeranian Stage
6a - a young-glacial area covered by older stages of the Wisła glaciation (with outwash plains)
5b - an old-glacial area within the Warta glaciation limits
5a - an old-glacial area older than the Warta glaciation
4 - a transitional area of upland/old-glacial relief
3 - uplands and old mountains
2 - intermountain basins
1 - mountains



Poland's first map of landforms geodiversity



Map of landform energy

GEODIVERSITY
VERY HIGH
HIGH
MEDIUM
LOW
VERY LOW

1. high-mountain relief transformed by glacial and periglacial processes, with arêtes and gullies
2. medium and low mountains and high foothills, a dense network of both valleys and ridges, ridges of end moraines densely fragmented in the lakeland belt, linear tectonic and denudation thresholds with steep slopes as well as high and precipitous (often also densely incised) scarps of gorges and cliffs
3. the elevated fragments of uplands, low foothills, and loess plateaux usually fragmented by a dense network of gullies, young-glacial morainic plateaux within the limits of the Pomeranian Stage, low tectonic and denudation thresholds as well as cliffs and deeper river gorges
4. intramontane basins, stretches of low uplands, plateaux with Pleistocene cover, poorly fragmented loess plateaux, young-glacial morainic plateaux within stages older than the Pomeranian Stage and compact fields of inland dunes, scarps of varying genesis
5. valley floors (margins of river terraces were omitted), sandy plains often of an outwash origin (sometimes with single dunes), old-glacial morainic plateaux, and coastal plains

Conceptual analysis

Proposed by L.Starkel (1998)

Map of landform fragmentation

A.Kostrzewski, L.Starkel, Zb.Zwoliński 1998

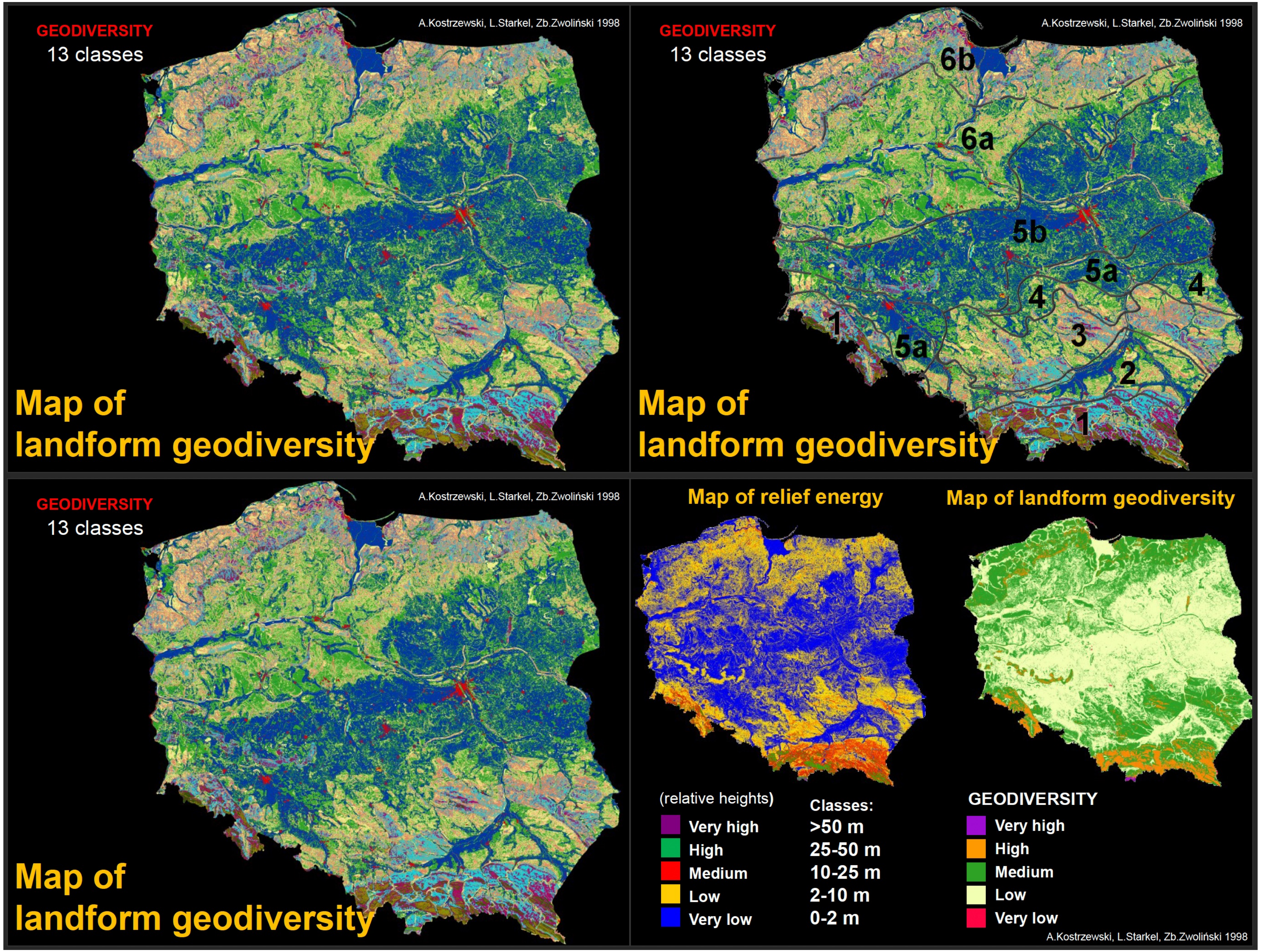
A.Kostrzewski, L.Starkel, Zb.Zwoliński 1998

Map of landform preservation

- **very high geodiversity** - a very high level of relief preservation; the morphological surface is the least transformed by morphogenetic processes and almost untouched by man-made processes.
- **high geodiversity** - a high level of relief preservation; areas sporadically affected by morphogenetic processes with a slight contribution of man-made processes.
- **medium geodiversity** - a medium level of relief preservation as a result of both morphogenetic and man-made processes.
- **low geodiversity** - a poor level of relief preservation indicating substantial changes in the relief as a result of human activity.
- **very low geodiversity** - a very poor level of relief preservation meaning a complete transformation of the relief by man, the transformation being usually irreversible.

From natural processes/ landforms

to anthropogenic processes/ landforms


GEODIVERSITY
13 classes
A.Kostrzewski, L.Starkel, Zb.Zwoliński 1998
Map of
landform geodiversity
GEODIVERSITY
13 classes
A.Kostrzewski, L.Starkel, Zb.Zwoliński 1998
6b
6a
5b
5a
4
4
3
2
1
5a
1
Map of
landform geodiversity
GEODIVERSITY
13 classes
A.Kostrzewski, L.Starkel, Zb.Zwoliński 1998
Map of
landform geodiversity
Map of relief energy
Map of landform geodiversity
(relative heights)
Classes:
Very high >50 m
High 25-50 m
Medium 10-25 m
Low 2-10 m
Very low 0-2 m
GEODIVERSITY
Very high
High
Medium
Low
Very low
A.Kostrzewski, L.Starkel, Zb.Zwoliński 1998

Qualitative methods – Expert classification

Table 2. Geodiversity assessment in Poland

Elements		Classes: A very high	B high	C moderate	D low	E very low
Geology — geodiversity		very high	high	moderate	low	very low
Relief	relief energy	areas >500 m a.s.l.	areas 200–520 m a.s.l.	areas 100–200 m a.s.l.	areas 40–100 m a.s.l.	areas >40 m a.s.l.
	relief diversity	high mountains	moderately high mountains	high uplands	intramontane valleys	lowland valley bottoms, coastal lowlands
	relief preservation	forestes, swamps, lakes	meadows, pastureland	arable land	urban areas	industrial, mining, and infrastructure areas
	total assessment	very high	high	moderate	low	—
Soils	agriculture production space, after JUNG	>90 pts	90–70 pts	70–50 pts	50–30 pts	<30 pts
	surface water erosion	very strong	strong	moderate	small	minimal
Surface water	water springs (discharge in l/s)	>100	50–100	20–50	5–20	
	wetland	in national parks and reserves	undeveloped areas		developed areas	drained degraded and contaminated areas
	lakes (water quality)	class I	class II	class III	substandard waters, river waters	substandard waters (stagnant)
	rivers (wilderness)	natural channels in law-protected areas	natural channels in agricultural areas	stabilizes river banks	regulated river channels	channelized rivers
	rivers (water quality)	class I	class II	class III	contaminated by municipal sewage	contaminated by industrial and municipal sewage
Landscape structure	landscape (geodiversity)	very high	high	moderate	low	very low
	human impact on natural environment (anthropopressure)	environmental reinforcement	marshy meadow vegetation succession	small changes in land use	strong changes in land use	impact of urban areas and motorways

Kozłowski 2004.

Intuition-based classification

Geodiversity assessment methods

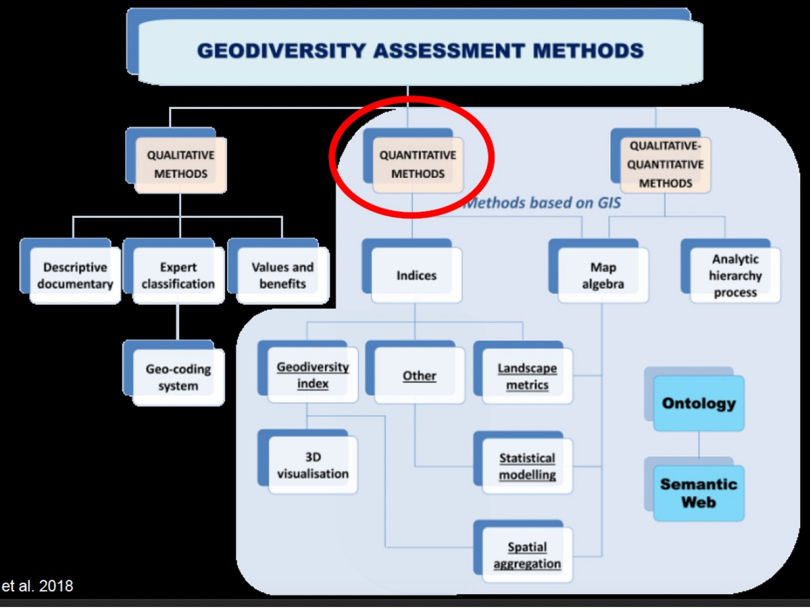
A. Concerning the source data:
   A. Direct methods,
   B. Indirect methods.

(Pellitero et al., 2014)

B. Concerning the procedure:
   A. Qualitative methods,
   B. Quantitative methods,
   C. Qualitative-quantitative methods.

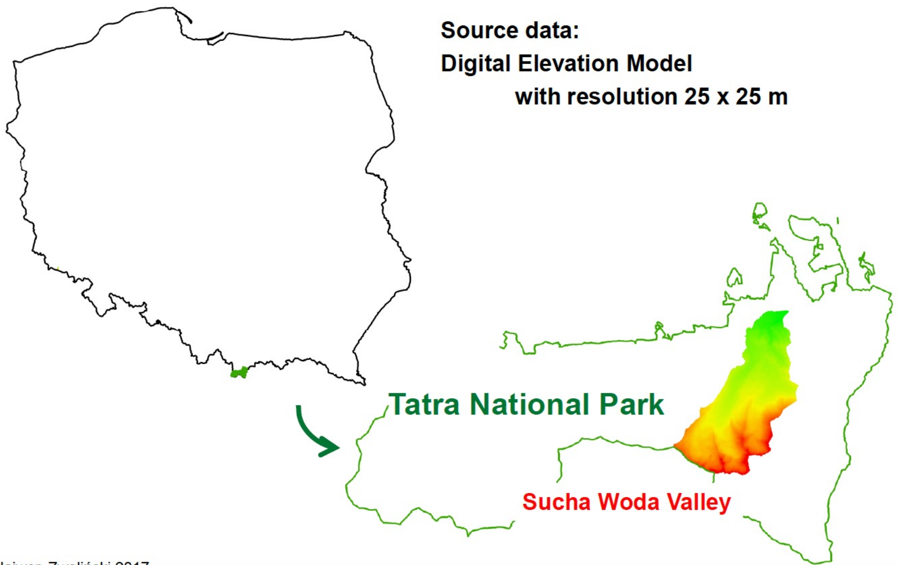
(Zwoliński et al., 2018)

Concerning the procedure



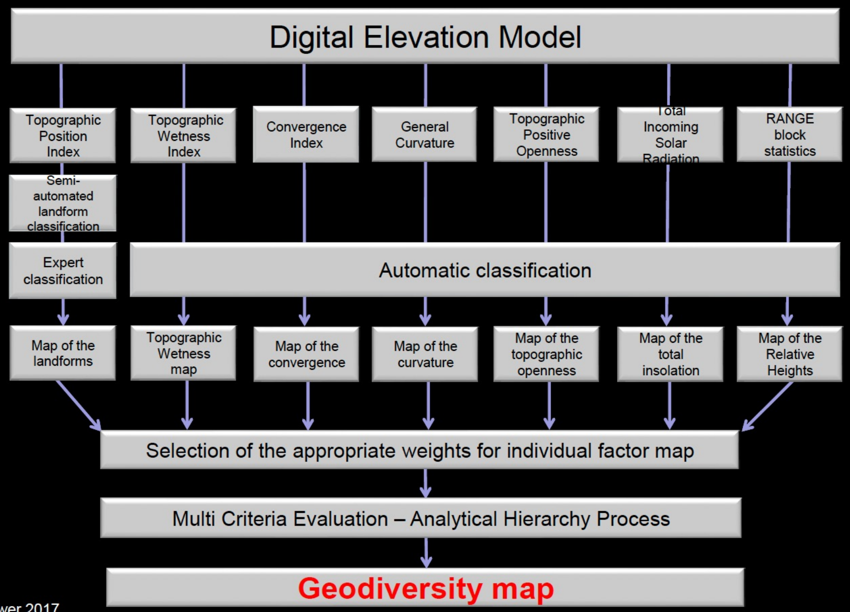
Zwoliński et al. 2018

Geodiversity computed from Digital Elevation Model



Najwer, Zwoliński 2017

Geodiversity computed from Digital Elevation Model



Najwer 2017

MCE - Multi-Criteria Evaluation

❖ **Multi-criteria analysis (MCE - Multi-Criteria Evaluation) is based on supporting the decision-making process in the case of having several criteria. Its goal is to achieve one common result.**

Three methods of MCE multi-criteria analysis:

1. Boolean method,
2. **method of linear weighing (i.e. WLC, Weighted Linear Combination),**
3. ordered weighted average method (OWA).

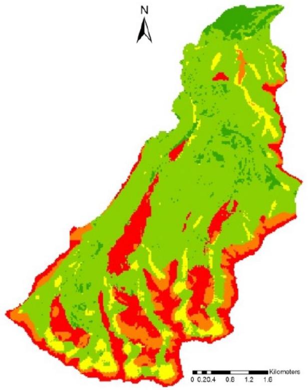
Qualitative-quantitative methods Analytic hierarchy process (AHP)

- AHP is widely accepted and used in many scientific disciplines as a hierarchical method for making complex decisions on the basis of criteria recognized with an expert system.
- The criteria for assessing geodiversity are primarily individual components of the geographical environment, but they can also be represented by geomorphometric parameters (e.g. TPI - Topographical Position Index, TWI - Topographical Wetness index, Solar Radiation etc.).
- Possibility of combining qualitative criteria with quantitative ones.

Geodiversity computed from Digital Elevation Model

Data optimization to the 5 classes with expert classification

Topographic Position Index



Sucha Woda Valley

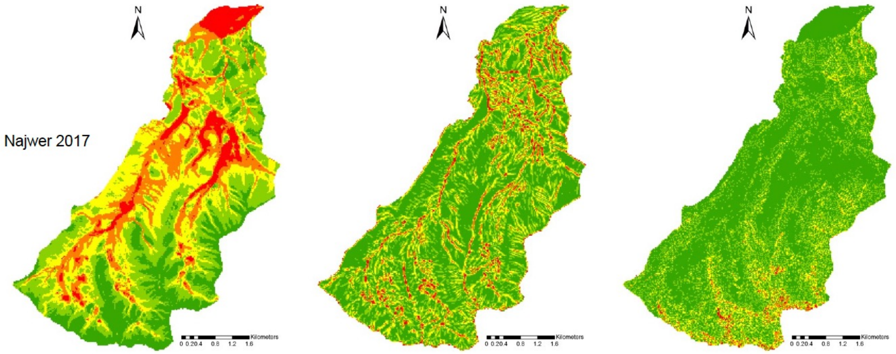
Expert classification	Landforms TPI ArcGIS
5 - very high geodiversity	Mountain Tops, High Ridges, U-shaped Valleys
4 - high geodiversity	Canyons, Deeply Incised Streams, Upland Drainages, Headwaters, Upper Slopes, Mesas
3 - medium geodiversity	Local Ridges, Hills in Valleys, Midslope Drainages, Shallow Valleys
2 - low geodiversity	Open Slopes, Midslope Ridges, Small Hills in Plains
1 - very low geodiversity	Plains

- Topographic Position Index (TPI) grids were calculated from DEM with circular moving window of 250 map cells radius, and biggest 1000 map cells (acc. to Weiss 2001)

Najwer 2017

Geodiversity computed from Digital Elevation Model

Data optimization to the 5 classes with Jenks natural breaks classification



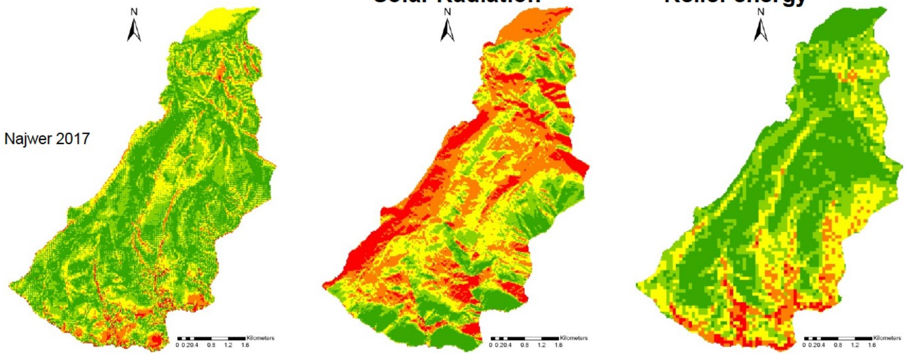
Convergence index is a terrain parameter which show the structure od the relief as a set of convergent areas (channels) and divergent areas (ridges)
Gradient calculation in the 3x3 map cells moving window.

Sucha Woda Valley

Geodiversity Very low | Low | Medium | High | Very High

Geodiversity computed from Digital Elevation Model

Data optimization to the 5 classes with Jenks natural breaks classification



Landform energy – block statistic calculations (rectangle 3x3 map cells)

Sucha Woda Valley

Geodiversity Very low | Low | Medium | High | Very High

Analytic Hierarchy Process (AHP)

- The weights for individual components have been calculated using the Saaty's pair comparison method:

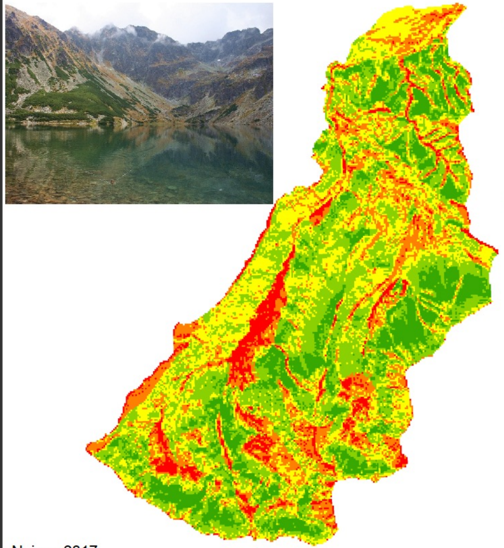
Topographic Position Index (TPI):	0.2259
Topographic Wetness Index (TWI):	0.2259
Total insolation:	0.2111
Convergence Index:	0.1299
Relief energy:	0.0753
General curvature:	0.0751
Topographic openness:	0.0568

Consistency Ration CR = 0.05
CR Index < 0.10 is accepted

Najwer 2017

Geodiversity computed from Digital Elevation Model

Geodiversity map of the Sucha Woda Valley

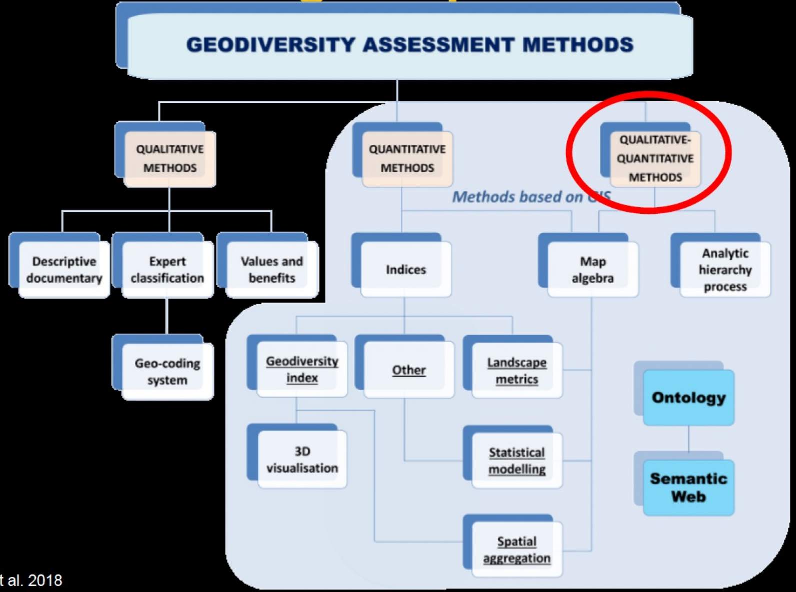


- Significant fragmentation of the value of geodiversity, especially in the lower, northern part of the catchment
- The highest geodiversity values are assigned to the upper, ridged, southern parts of the catchment

Geodiversity	
Very low	16%
Low	31%
Medium	28%
High	18%
Very High	7%

Najwer 2017

Concerning the procedure



Zwoliński et al. 2018

Qualitative-quantitative methods

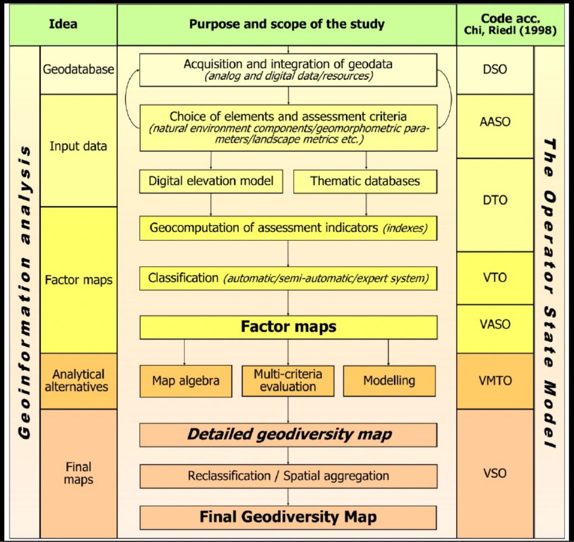
- **Qualitative-quantitative methods** are a good combination for supporting the collection of quantitative data (i.e. digital) and cause-effect data (i.e. relational and explanatory).

Their particular advantage is:

- the integration of data from different sources and with different substantive content,
- the possibility of applying evaluations based on numerical processing of geodiversity, and expert system knowledge as well.

Zwoliński et al. 2018

Qualitative-quantitative methods



Najwer, Zwoliński 2014

Qualitative-quantitative methods
Analytic hierarchy process (AHP)

Geodiversity assessment criteria

Factor maps	Source data	Classification method	Parameters	Geodiversity scale
Lithological	Detailed geological map of Poland 1:50 000	Expert classification	peats; loams; humus sands; gyttjas and lacustrine chalk; calcareous tufa	1 - very low
			lake sands, silts and clays; ice-dammed clays, silts and sands	2 - low
			glacial sands and gravels; outwash sands and gravels; fluvioglacial sands and gravels; kame sands and silts; sands and gravels of crevasse accumulation and eskers; alluvial sands of valley floors and floodplains; alluvial sands of river terraces; aeolian sands	3 - medium
			end-moraine gravels, sands, boulders and tills; colluvial sands and clays	4 - high
			glacial tills	5 - very high
Relative heights	30-meter Digital Elevation Model (DTED 2)	Automatic classification with a natural breaks method (Jenks 1967)	Hw: 0-2.3 m	1 - very low
			Hw: 2.4-4.5 m	2 - low
			Hw: 4.6-7.5 m	3 - medium
			Hw: 7.6-11.8 m	4 - high
			Hw: 11.9-29.7 m	5 - very high
Landform fragmentation		Semi-automatic classification and expert classification	valleys; lower slopes	1 - very low
			gentle slopes	2 - low
			upper slopes	3 - medium
			steep slopes	4 - high
			ridges	5 - very high

Najwer et al. 2016

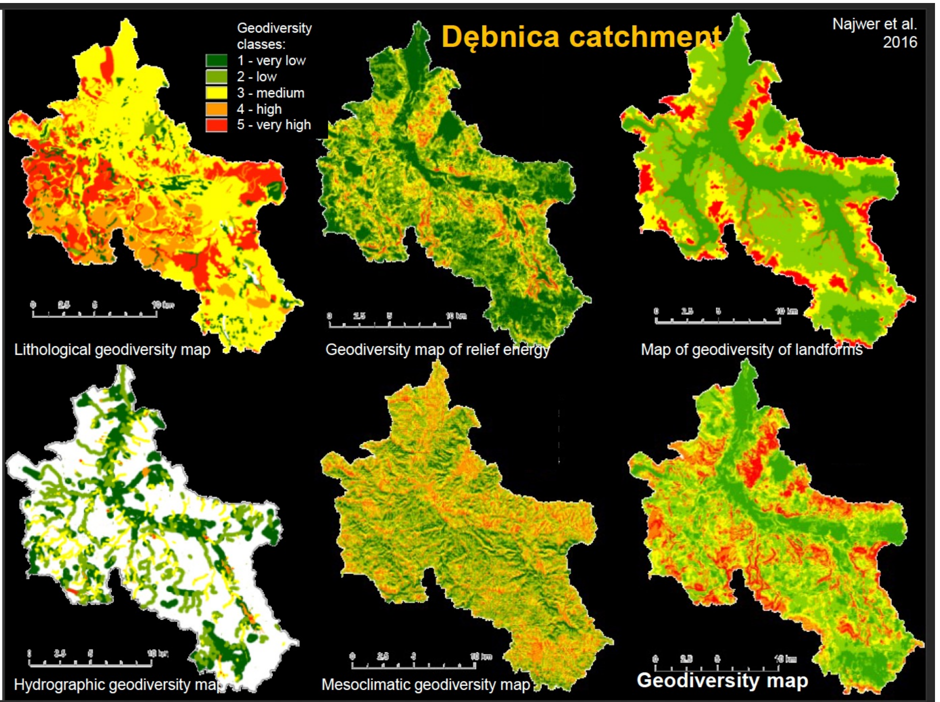
Qualitative-quantitative methods
Analytic hierarchy process (AHP)

Geodiversity assessment criteria

Criteria	Source	Method	Parameters	Class
Hydrographical elements	Map of Hydrological Division of Poland in the scale 1:50 000; field mapping	Automatic classification with a natural breaks method (Jenks 1967)	A: 0.0-0.6 ha; K: 77-579 m ha^{-1} S: 0.0-1.2‰, Br: 250 m Qz: 0-1 l s^{-1}; type: linear seep, Bz: 30 m	1 - very low
			A: 0.7-2.7 ha; K: 580-955 m ha^{-1} S: 1.3-2.4‰; Br: 150 m Qz: 1-5 l s^{-1}; type: bog-spring, Bz: 60 m	2 - low
			A: 2.8-7.2 ha; K: 956-1235 m ha^{-1} S: 2.5-4.0‰; Br: 100 m Qz: 5-10 l s^{-1}; type: seepage spring, Bz: 90 m	3 - medium
			A: 7.3-23.7 ha; K: 1236-1508 m ha^{-1} S: 4.1-7.1‰; Br: 50 m Qz: 10-20 l s^{-1}; spring and linear outflows, Bz: 120 m	4 - high
			A: 23.8-56.1 ha; K: 1509-2245 m ha^{-1} S: 7.2-16.1‰; Br: 25 m Qz: 10-100 l s^{-1}; type: seepage spring area, Bz: 150 m	5 - very high
Climatological	30-meter Digital Elevation Model (DTED 2)	Automatic classification with a natural breaks method (Jenks 1967)	TWI: 8.4-10.5; K↓: 2.1-3.8 kWh m^{-2}	1 - very low
			TWI: 10.6-11.5; K↓: 3.9-4.1 kWh m^{-2}	2 - low
			TWI: 11.6-12.6; K↓: 4.2-4.3 kWh m^{-2}	3 - medium
			TWI: 12.7-13.9; K↓: 4.4-4.5 kWh m^{-2}	4 - high
			TWI: 14-17.9; K↓: 4.6-5.6 kWh m^{-2}	5 - very high

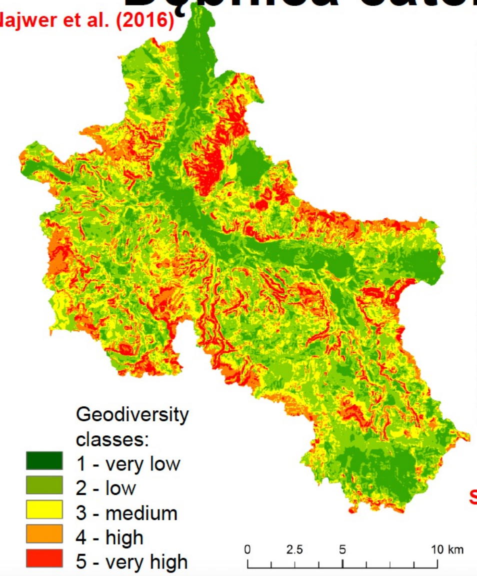
Symbols: Hw - relative height, TPI - Topograhic Position Index, A - lake surface area, K - shoreline development index, S - parts with the average slope, Br - buffer along the river parts with a radius of..., Qz – groundwater discharge, Bz - buffer around the groundwater outflows with a radius of..., TWI - Topographic Wetness Index, K↓ - Total Insolation

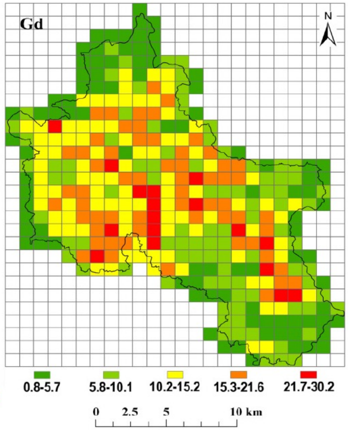
Najwer et al. 2016



Geodiversity and biodiversity
Dębnica catchment

Najwer et al. (2016)

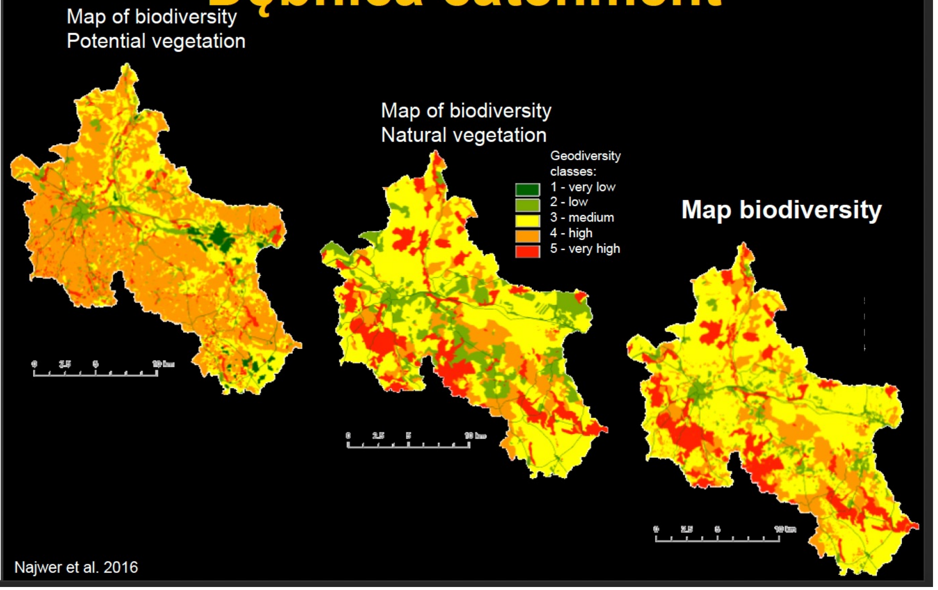




Serrano & RuizFlaño (2007)

Zwoliński et al. 2018

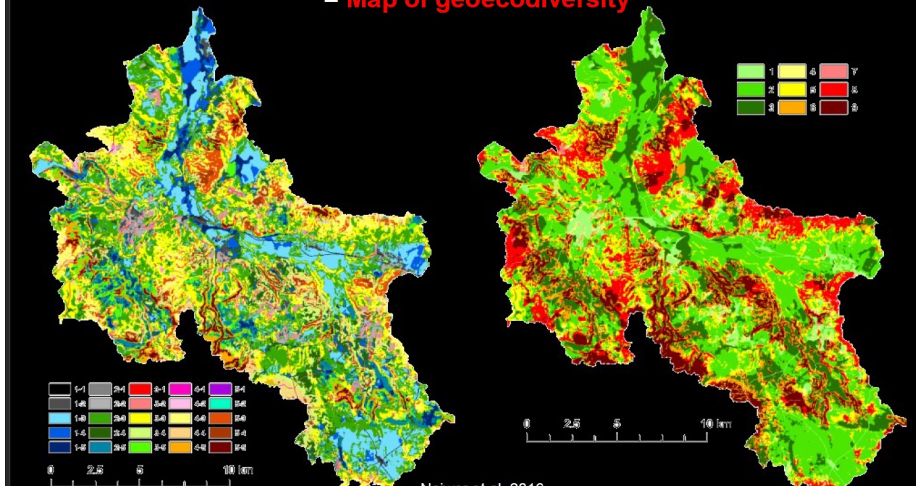
Geodiversity and biodiversity
Dębnica catchment



Najwer et al. 2016

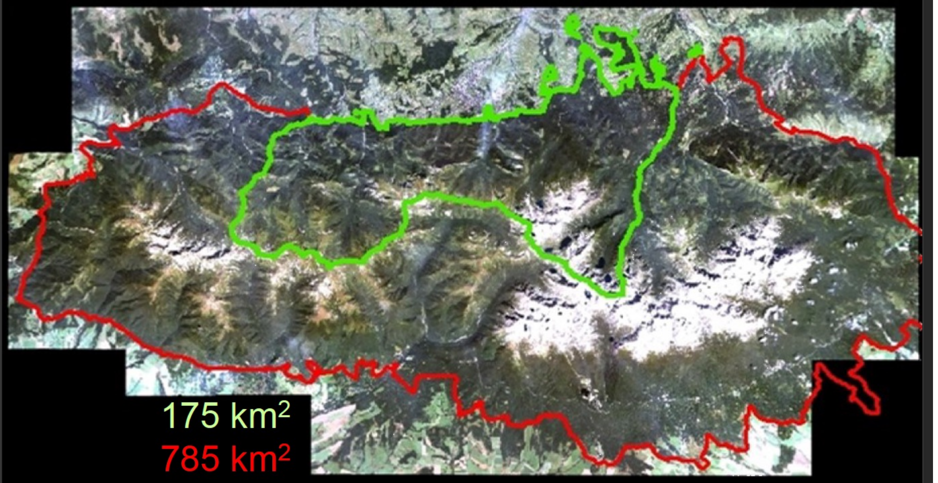
Geodiversity and biodiversity Dębnica catchment

Map of geodiversity + Map of biodiversity
= Map of geoecodiversity



Najwer et al. 2016

Border (green) of the Polish Tatras on the background of the whole (red) Tatra Mts

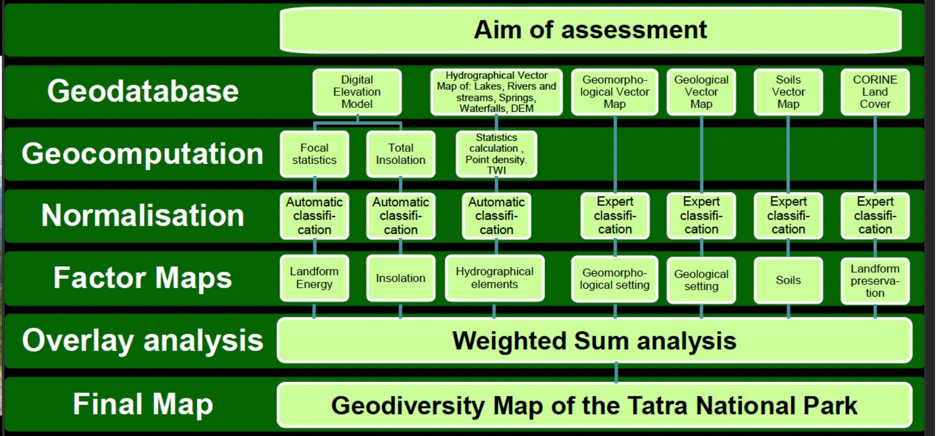


Tatra Mts.

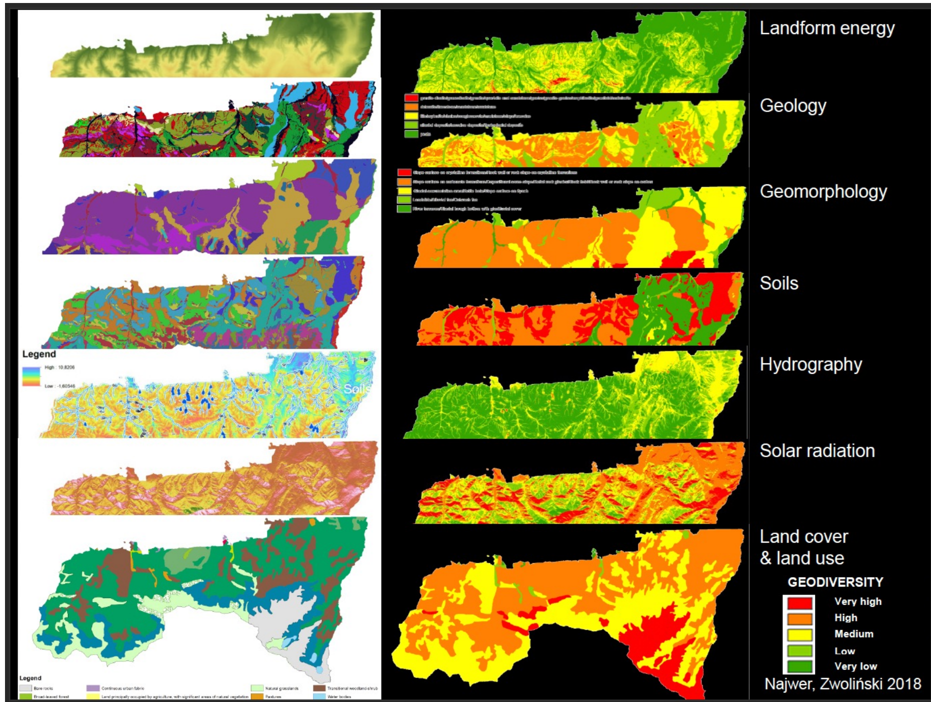
High Tatras

Western Tatras

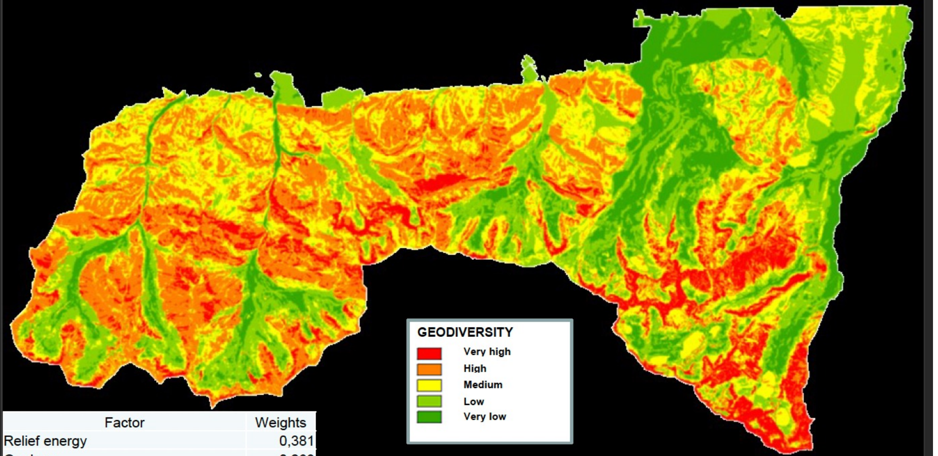
Workflow for Tatra Mts



Najwer, Zwoliński 2018



Geodiversity of the Tatra Mts



Factor	Weights
Relief energy	0,381
Geology	0,263
Geomorphology	0,096
Hydrography	0,103
Soils	0,095
Insolation	0,037
Land cover Land use	0,025
Total	1,000

Najwer, Zwoliński 2018

Conclusions – to take home

1. **Geodiversity** is valuable from a variety of perspectives like geomorphological, geological, geoecological, geoheritage, as well as cultural, educational, geotourist, social, and so on.
2. **Presented procedures** for delimitation of geodiversity are promising and better assign geodiversity degree for complex geoecosystems in quantitative approach than in qualitative (descriptive) approach.
3. Therefore landforms/landscapes with outstanding geodiversity should undergo **geoconservation** as a result of which it is possible to create geomorphosites or geoparks for present and future generations.